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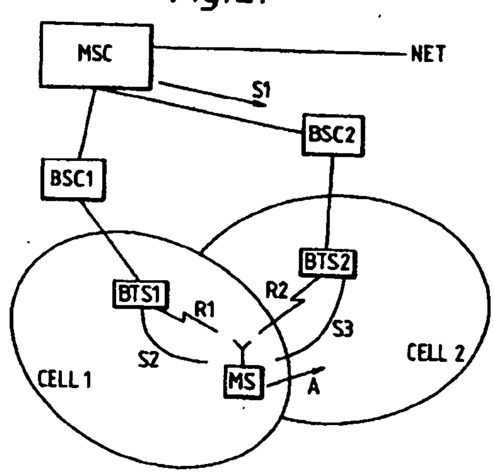
(54) **Apparatus and method for call handover in a cellular radio system.**

(57) In preparation of a handover from base station BTS1 to base station BTS2 parallel physical links (R1,R2) are formed between the mobile station MS and the two base stations (BTS1,BTS2), whereby these base stations (BTS1,BTS2) transmit the same signal to the mobile station MS in different time slots and possibly on different frequencies.

Fig. 2.

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The present invention relates to handover in a cellular radio system.

The switching of the base station is illustrated in Fig. 1 which shows the main components of a cellular network constructed in a way known per se. The system includes at least one center MSC (Mobile Services Switching Center) which is connected to a public telephone network NET, for instance. The center communicates with controllers BSC 1-3 (Base Station Controller) of the base station which controllers may comprise one or more base stations BTS (Base Transceiver Station). In addition, several mobile stations (MS) travel in the network in the zones (not shown) of the cells of the base stations BTS. For the sake of clarity only one mobile station, a mobile telephone in this instance, is illustrated. Intercommunications within the network can be established between mobile stations MS and/or between mobile station MS and network NET.

When travelling in the area of the network, mobile station MS can reach the border of the cell, i.e., coverage area of its current base station BTS, and a link has to be established with another base station BTS which is closer so that the mobile station can move from one cell of the network to another without an interruption occurring in the intercommunication in progress. In practice this means that when the base station is switched, the channel used between the mobile station and the base station is switched. In the TDMA system the channel means the time slot in which the procedures are carried out. (Switching the channel may also be required when moving within one cell.) The term "handover" is also used when speaking of channel switching and in Fig. 1 it is illustrated in curves a (switch 1) → 2)) and b (switch 2) → 3)).

In order to ensure an interference-free handover the mobile station monitors at regular intervals the quality of reception, for instance, the strength of the signal of its own base station and that of the next nearest base stations and sends the results to the base station BTS it uses at that moment, from where the data is directed to controller BSC and if so required, to center MSC. On the basis of the monitoring results the center, and in the future perhaps the mobile station as well, can specify a new base station for the mobile station and the exact moment for the handover, when, for example, the communication with the old base station has diminished.

Fig. 2 illustrates a situation where the mobile station MS is transferred from cell 1 of base station BTS1 to cell 2 of another base station BTS2. The transfer is illustrated in arrow A. Mobile station MS first communicates, on radio link R1, with base station BTS1, which monitors the power of the signal of MS during the communication and reports on it to center MSC, when a handover to base station BTS2 under base station controller BSC2 is expected to occur. Mobile station MS monitors once in a while (during the monitoring cycle), based on the neighbouring base station list it has received, the signal of its neighbouring base stations as well, in this case the signal of base station BTS2, and reports on it to BTS1. When the handover criterion is met, a message is signalled to base station controller BSC2 including the parameters required in recognizing mobile station MS and the data of the new channel (time slot) which will be used in communication between mobile station MS and base station BTS2. After preparation the handover to the new base station is performed, controlled by MSC. The signalling required in this operation is illustrated in arrows S1 to S3.

A perfect handover should occur without the user noticing any interferences. For this purpose, different methods for handover have been developed and researched in different cellular systems.

A soft handover is considered an advantage offered by the CDMA system. In the CDMA system (Code Division Multiple Access), several base stations are capable of receiving a signal transmitted by a mobile station by using the same code.

Similarly, several base stations may send the same signal to a mobile station using the same code, and the moving station receives the signals like signals coming through multipath propagation. The CDMA system is being developed for a digital mobile station network in the U.S.A., for instance. Another significant mobile station network system is based on the TDMA (Time Division Multiple Access) which is used or will be used, for instance, in the GSM system (Global System for Mobile Communication), the DECT system (Digital European Cordless Telephone) for cordless telephones, and the digital (ANSI) mobile station system in the U.S.A.

The soft handover described above with respect to the CDMA system could also be implemented in the TDMA system. Thus two or more base stations can receive a signal transmitted by a mobile station simultaneously. This is often referred to as macrodiversity. However, this requires that the base stations are either synchronized to each other (because otherwise the base stations cannot receive at the same time but the transmission bursts overlap in the other base station) or that the other base station uses a separate carrier and a receiver for reception. This type of arrangements make the network more complicated and its use more difficult.

In the above-mentioned cases, problems can also occur in the TDMA network regarding the exact adjustment of the time alignment of the mobile station because mobile station MS adjusts its transmission in accordance with one base station, but the same time alignment does not necessarily suit the other base station. On the other hand, the extended guard time between bursts could be used but this would lead to an unnecessarily large requirement for capacity.

In the TDMA system, it is possible to arrange so that two or more base stations send the same signal to the mobile station "simultaneously" by using the same time slot and carrier wave frequency. Such an operation is called "simulcasting" (sometimes also macrodiversity). This type of transfer would also require synchronization of the base stations. If the mobile station receives a signal from two base stations simultaneously (and the signals cannot be distinguished from each other within the resolution of the receiver) and if the signals are approximately equally strong, this will create a strong standing wave pattern in which the signals either strengthen or cancel each other, whereby the mobile station experiences this as strong fading. This type of fading can have a greater effect than fading due to multipath propagation. This problem could be solved by using a suitable delay between the base stations, whereby signals would arrive at the mobile station at different points in time and would not cancel each other but they could be utilized by a Viterbi type of receiver, for instance. However, adjusting the delay would be difficult, at least when the mobile station MS is moving. In addition, adjusting the delay would substantially increase the signalling between the base station and the mobile station. Besides, the adjustment of the delay must stay within a limited range because if the delay between the signals increases too much, the receiver is not able to use both signals. Simulcasting also adds to the interference level of the whole network because a particular frequency is used in adjacent base stations.

According to the present invention there is provided apparatus for performing handover in a cellular radio system, wherein two different communication channels are utilised during the handover. This has the advantage in that it provides a simple solution for implementing reliable handover.

In a preferred embodiment of the invention there is further provided a first base station (BTS1) and a second base station (BTS2) and at least one mobile station (MS), and wherein there is provided means for communicating between the second base station (BTS2) and the at least one mobile station (MS) via a second base station (BTS2) communication channel which is different to a communication channel utilized by the first base station (BTS1) for communicating with the at least one mobile station (MS) during handover between the first base station (BTS1) and the second base station (BST2). Due to the fact that the mobile station (MS) communicates with two or more base stations (BST) during handover, there is a low likelihood that an interruption in communication will occur when the mobile station goes from one cell to another cell. Preferably, the cellular radio telephone system further comprises at least one mobile switching centre (MSC), and the selecting means is disposed at the at least one mobile switching centre (MSC) or first or second base station (BTS1,BTS2). This has the advantage that the circuitry necessary for implementing the selecting means is not included in the mobile station (MS). Thus, the mobile station (MS) can have a lower size and weight.

In another aspect of the invention there is provided a method for performing handover in a cellular radio telephone system comprising a first base station (BTS1) and a second base station (BTS2) and at least one mobile station (MS), wherein during handover of the at least one mobile station (MS) between the first base station (BTS1) and the second base station (BTS2), the second base station (BTS2) is able to communicate with the at least one mobile station (MS) by utilizing a different communication channel to the communication channel utilized by the first base station (BTS1) for communicating with the at least one mobile station (MS).

Specific embodiments of the invention will now be described by way of example only, and with reference to the drawings in which;

Fig. 1 represents the common structure of a mobile station network known per se;

Fig. 2 illustrates a situation where the mobile station moves from the cell of the base station to the cell of another base station;

Fig. 3 represents a GSM type of use of time slots, known per se;

Fig. 4 represents the use of time slots in a TDMA system using the method according to the invention;

Fig. 5 represents the use of time slots in a TDMA system by the method according to the invention, according to another alternative; and

Fig. 6 illustrates the principle and timing of the use of time slots in different communication directions.

Before considering the method according to the invention more closely, we will first examine a known use of time slots in a GSM type of telecommunication with the aid of Fig. 3. For the sake of clarity, only one time axis is used in the Figure for both mobile station MS and base station BS. The time axis goes from top to bottom and this is illustrated using increasing numbers in the slots. In this case frame Fr comprises eight time slots 0...7, in other words, the GSM system uses a frame of 8 time slots or channels. The figure shows two sequential frames FrN and FrN+1. In the example the mobile station transmits in time slot 4 and the base station transmits in time slot 1. Marking "Mon" refers to the monitoring cycle of the mobile station which we already referred to in the common part when describing Figs. 1 and 2. During the Mon cycle the MS monitors the signal of the neighbouring base stations. The monitoring does not have to coincide accurately within the time slot limits; in the Figure, Mon is shown in time slot 6 but it could just as well be situated somewhere between time slots 6 and 7, for instance.

Fig. 6 represents the ETSI/GSM proposal for the order of the time slots and an example has been added to it where mobile station MS receives in time slot 3/Rx (Downlink) from its "own" base station (serving cell). Then the MS transmits (Uplink) in another time slot 3/Tx. Somewhere in between the MS monitors the signals of neighbouring base stations (adjacent cells). This Figure shows more clearly how different the timing of the base station and the mobile station can be in practice, even though only one time axis is used in Figs. 3, 4, and 5 for the sake of clarity.

The method according to the invention is advantageously applied in a case where the so-called TDMA ratio is high; the examples of Figs. 4 and 5 use 24 time slots per frame.

In the example of Fig. 4 the MS uses two perfect physical links during the switching of base stations, i.e., the soft handover, according to the invention. Thus mobile station MS receives in time slot 1 from its own base station BS1 and transmits in time slot 10 to its own base station. The time slot number of the other base station BS2 is selected for the mobile station within the available window W1/W2, whereby reception window W1(Rx) and transmission window W2(Tx) are situated symmetrically in frame FrN. Fig. 4 shows only two sequential frames FrN and FrN+1. The window (W1/W2) in which the MS is able to communicate with the other base station BS2 depends on the speed of the synthetizer of the MS. In the example of Fig. 4, the MS uses two perfect physical links, whereby the absolute timing of the other base station is not significant. In this situation, the cells of both base stations BS1, BS2 use frequencies within the normal frequency planning or those within the dynamic channel allocation. Enough capacity for one channel only is reserved from the other base station BS2 for the preparation and execution of the handover.

Fig. 5 represents another alternative of the method according to the invention. This requires that the alternative second base station BS2 uses a separate receiver which possibly deviates from its own synchronization, or alternatively, that base stations BS1 and BS2 are synchronized with each other, whereby base station BS uses a fast synthesizer for changing the frequency. Thus the second transmission of the mobile station MS can be removed, i.e., MS only transmits once and both base stations receive the same time slot as presented in time slot 10. Thus the other base station BS2 "listens" to the same transmission as the user's "own" base station BS1. However, MS receives separately from both base stations, as depicted by time slots 1 and 2. Window W3 in which the MS is able to communicate with the other base station BS2, depends on the speed of the synthesizer of the MS.

In the case of Fig. 5 the transmission of the second base station BS2 can be in the frequency band normally reserved for the cell, which is preferred in the frequency planning, but in this case it reserves capacity from the normal communication of the cell of BS2.

In Figs. 4 and 5 the transmission and reception of the TDMA structure is separated into separate periods, but the principle according to the invention functions also if the transmission/reception of the user's own base station BS1 is placed into a group within the switching time of the synthesizer. However, the alternatives according to Figs. 4 and 5 are more advantageous in, for instance, the practical implementation of the signal processing of the receiver and the transmitter.

It can be seen from the above that, according to the invention, a phase is added to the "hard" handover of the base station known per se, in which phase the mobile station MS communicates simultaneously with two (or more) neighbouring base stations. In the embodiment described the soft handover method according to the invention for enhancing the switching of the base station comprises phases in which mobile station MS

a) periodically monitors (Mon) the signal sent by the nearest base stations (BTS1, BTS2),

b) sends its respective monitoring results to the base station (BTS) and/or the center (MSC), whereby

c) the base station or the center, on the basis of the monitoring result it has received and predetermined criteria, further directs the mobile station (MS) to form parallel links to two or more base stations for preparing the handover, whereby the switching of the base station is implemented by disconnecting one channel (R1 in Fig. 2) or all other channels but the selected new channel (R2). In the case of several base stations, forming and disconnecting the physical links does not necessarily have to be performed at the same time. The parallel physical links to two (or more) base stations formed according to the invention remain coupled for about 0,5...10 seconds, in practice about 1 or 2 seconds, depending on the properties of the system and the cell structure. The parallel linking time is preferably adjustable if so required. In the usual way the level of the signal, the level of interferences, etc., is used as the criterion for switching the base station. The link to the previous base station (for instance BS1 or BTS1) is switched off when the MS has moved under the effect of the other base station (BS2 or BTS2) and into its cell. In the above, the base station or the center controls the switching of channels; alternatively also the mobile station can direct the handover in question.

Thus, according to the invention a soft handover of the base station or channel is performed, whereas according to the known technique a hard handover of the base station is performed in which the MS re-

spectively communicates with only one base station at a time.

In the handover according to the invention two or more base stations in a TDMA system transmit the same signal to the mobile station in a different time slot and possibly on a different frequency. Thus, at least the data of the user is the same, even though the signalling data (S2, S3 in Fig. 2) for different base stations can be different. In the example of Fig. 4, MS transmits in a different time as well, i.e., in a different time slot to different base stations. Also in this case at least the user's data is the same while the signalling data for different base stations can be different. In the example in Fig. 4 the base stations need not be synchronized; pseudosynchronization is sufficient, whereby MS always knows the relative time difference between base stations (see Fig. 6, for instance) and it can accommodate its own transmission and reception separately for each base station. The fading phenomenon due to standing wave pattern is not created because signals from different base stations do not arrive in the mobile station at the same time, consequently, no adjustment of the transmission delays of the base stations is required. MS simply counts the necessary transmission and reception moments. When using the method according to the invention, no extended guard times between bursts are needed either.

The solution according to the invention for handover does increase the need for signal processing in the mobile station since it has to receive two bursts. The need for signal processing can be decreased if, at an early stage, one of the bursts is marked so poor that it is not worth processing further, which could be considered selection diversity. On the other hand, the received signals could also be buffered and combined in a suitable stage so that the quality of communication is enhanced. The combining can be performed, as is known, for instance, by summing the signals as cophased before detection or by combining the signals in the channel equalizer or in the error correcting circuit or in the source decoder (for instance, a speech decoder), etc. The selection can also be performed, as is known, in subsequent phases (before detection, after the equalizer, after the error correcting circuit, after the source decoder, etc.). Correspondingly, the selection or combining can also be performed in the base station side, whereby the selection or combining would, however, be carried out in the base station controller or the center.

Transmission of two bursts (to two base stations) naturally consumes more power than the conventional communication to one base station at a time but, on the other hand, it should be taken into account that a momentary peak power does not increase because there is a time difference between bursts. Consequently, the application of the method according to the invention requires no changes in the power amplifier of the transmitter of the mobile station. The generation of the burst can be performed once, after which it is sent in the TDMA system in two time slots so that the need for signal processing required by two transmissions is not necessarily doubled.

In the case of Fig. 5 the soft handover is performed so that two separate transmissions are used for the preparation and the switching only when transmitting from the base station towards MS. Thus MS only sends once and several base stations receive the same signal (macrodiversity). In this way the power consumption of the MS can be saved. However, this alternative method includes drawbacks such as the problems mentioned in the beginning related to macrodiversity.

The soft handover according to the invention functions especially well in a TDMA system with a high TDMA ratio. Thus the base station has more alternatives for selecting a time slot which suits well the mobile station in question so that the MS has enough time to change the frequency between bursts, for instance, if so required. In a GSM type of system in which a frame comprises eight time slots (8-TDMA), this method according to the invention can be used as well, as long as the synthetizers, for instance, are fitted in a corresponding way so that the mobile station has time to change the frequency between bursts if so required.

The above-described method can also be used, according to the invention, in CDMA and FDMA systems. Thus two codes need to be used in the CDMA system and in the FDMA system, two channels.

According to a modification of the invention the mobile station is capable of being in signalling communication with both base stations, or via them to center MSC, for instance, if so required. Thus the signalling can be arranged in a more reliable way in difficult cases.

In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed by the present invention. The applicant hereby gives notice that new claims may be formulated to such features during prosecution of this application or of any such further application derived therefrom.

## Claims

1. Apparatus for performing handover in a cellular radio system, wherein two different communica-

tion channels are utilized during the handover.

2. Apparatus according to claim 1, further comprising a first base station (BTS1) and a second base station (BTS2) and at least one mobile station (MS) and wherein there is provided means for communicating between the second base station (BTS2) and the at least one mobile station (MS) via a second base station (BTS2) communication channel which is different to a communication channel utilized by the first base station (BTS1) for communicating with the at least one mobile station (MS) during handover between the first base station (BTS1) and the second base station (BTS2).

3. Apparatus according to claim 2, further comprising:
   a) monitoring means for monitoring signals transmitted to the mobile station (MS) from the first base station (BTS1) and the second base station (BTS2), and
   b) selecting means for selecting the second base station (BTS2) communication channel for communicating between the at least one mobile station (MS) and the second base station (BTS2) when an output from the monitoring means fulfils a predetermined criterion.

4. Apparatus according to claim 3, wherein the cellular radio telephone system further comprises at least one mobile switching centre (MSC), and the selecting means is disposed at the at least one mobile switching centre (MSC) or first or second base station (BTS1, BTS2).

5. Apparatus according to claim 4, wherein the selecting means is operable in accordance with an output from the monitoring means and transmitted to the mobile switching centre (MSC) or base station (BTS).

6. Apparatus according to claim 3, wherein the selecting means is disposed in the at least one mobile station (MS).

7. Apparatus according to any preceding claim, wherein the cellular radio telephone system is substantially a time division multiple access (TDMA) system.

8. Apparatus according to claim 7, wherein the second base station (BTS2) is adapted to communicate with the mobile station (MS) by using a different time slot to the time slot utilised by the first base station (BTS1) for communicating with the at least one mobile station (MS).

9. Apparatus according to claim 7 or claim 8, wherein a TDMA frame comprises at least eight time slots.

10. Apparatus according to any of claims 7 to 9, wherein at least the user's data is the same in different time slots.

11. Apparatus according to any of claims 2 to 10, wherein the second base station (BTS2) communicates with the at least one mobile station (MS) via a different communication channel to the communication channel utilised by the first base station (BTS1) for communicating with the mobile station (MS) for at least 0.5 seconds.

12. Apparatus according to any of claims 2 to 11, wherein communication between the base stations (BTS1, BTS2) and the at least one mobile station is buffered and combined in order to improve the quality of the communication.

13. Apparatus according to any of claims 3 to 12, wherein the predetermined criterion is that the signal to noise ratio in the second base station (BTS2) communication channel is greater than the signal to noise ratio in the communication channel utilised by the first base station (BTS1).

14. A method for performing handover in a cellular radio telephone system comprising a first base station (BTS1) and a second base station (BTS2) and at least one mobile station (MS), wherein during handover of the mobile station (MS) between the first base station (BTS1) and the second base station (BTS2), the second base station (BTS2) is adapted to communicate with the at least one mobile station (MS) by utilizing a different communication channel to the communication channel utilized by the first base station (BTS1) for communicating with the at least one mobile station (MS).

15. A method for enhancing handover in a digital cellular radio telephone system based on time division multiple access (TDMA) which comprises at least one center (MSC) and several base stations (BTS) and mobile stations (MS), characterized in that for the time of preparation and execution of the handover, parallel physical links are formed between the mobile station (MS) and two or more base stations (BTS1, BTS2) by using a different time slot between the mobile station (MS) and various base stations (BTS) in at least one of the communication directions.

16. A method for enhancing handover in a digital cellular radio telephone system based on time divi-

sion multiple access (TDMA) which comprises at least one center (MSC) and several base stations (BTS) and mobile stations (MS) and in which

a) the mobile station (MS) periodically monitors the signal sent by the nearest base stations (BTS1, BTS2), and

b) the mobile station (MS) is directed, on the basis of the monitoring results and predetermined criteria, to switch into a channel of another base station, for the handover, **characterized** in that, on the basis of the monitored results and predetermined criteria, the mobile station (MS) is directed to form links with two or more base stations (BTS1, BTS2) in parallel for the preparation of the switching of the base station by using a different time slot between the mobile station (MS) and various base stations (BTS) in at least one of the communication directions, whereby switching of the base station is implemented by switching off one channel (R1) or all other channels but the selected new channel (R2).

Fig.1.

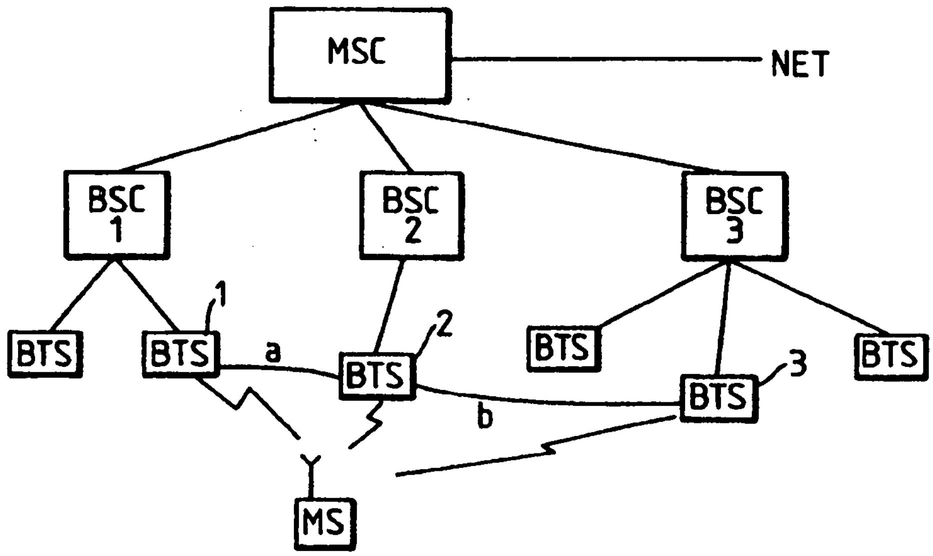

MSC
NET
BSC 1
BSC 2
BSC 3
BTS
BTS
1
a
BTS
2
BTS
BTS
3
BTS
b
MS

Fig.2.

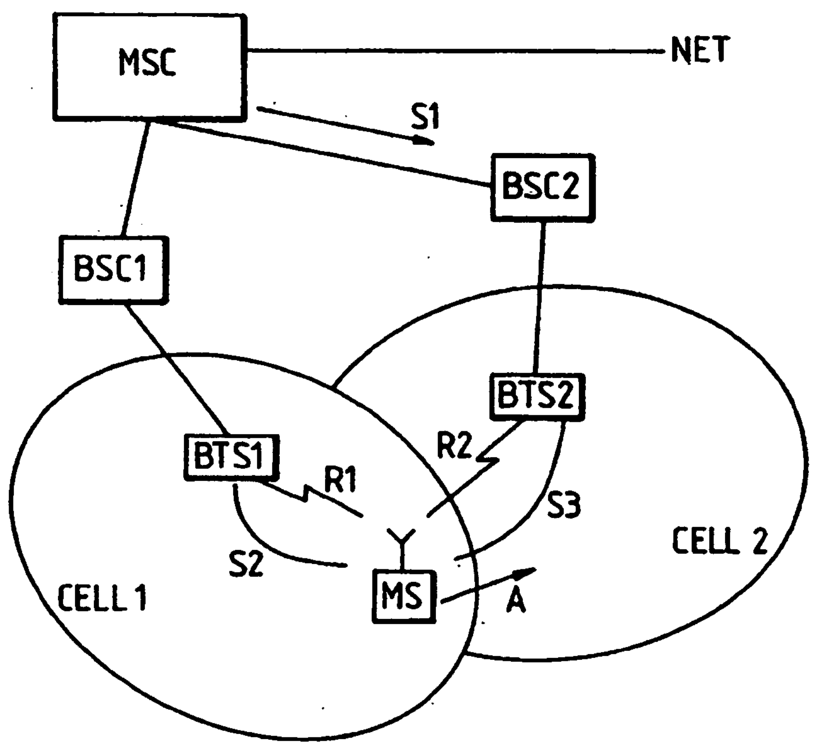

MSC
NET
S1
BSC2
BSC1
BTS2
BTS1
R2
R1
S3
S2
CELL 2
CELL 1
MS
A

*Fig.3.*

| slot | MS | BS | |
|---|---|---|---|
| 0 | | | |
| 1 | Rx | Tx | |
| 2 | | | |
| 3 | | | Fr N |
| 4 | Tx | Rx | |
| 5 | | | |
| 6 | Mon | | |
| 7 | | | |
| 0 | | | |
| 1 | Rx | Tx | |
| 2 | | | Fr N+1 |
| 3 | | | |
| 4 | Tx | Rx | |
| 5 | | | |
| 6 | Mon | | |
| 7 | | | |

Fig.4.

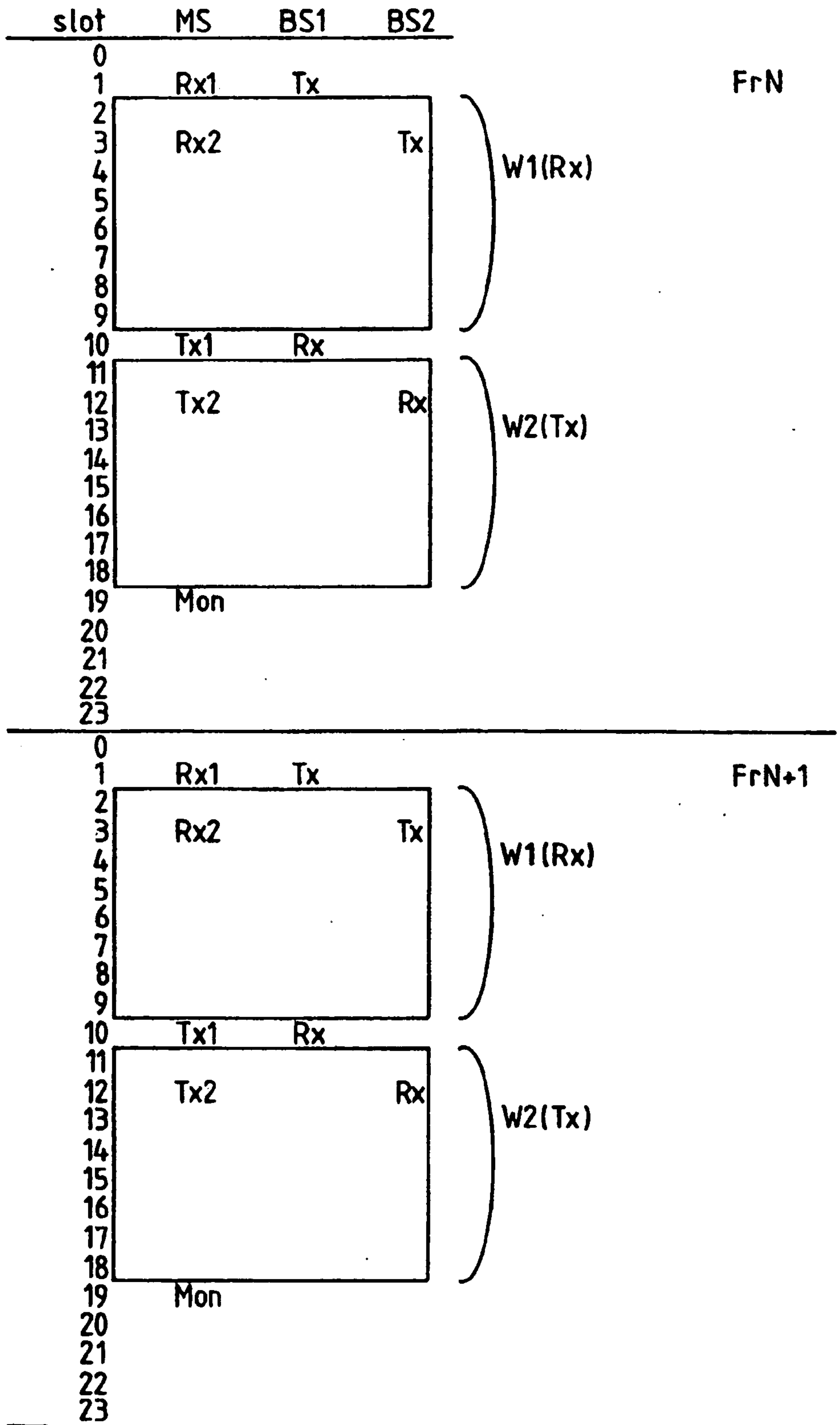

slot
MS
BS1
BS2
0
1
Rx1
Tx
FrN
2
3
Rx2
Tx
W1(Rx)
4
5
6
7
8
9
10
Tx1
Rx
11
12
Tx2
Rx
W2(Tx)
13
14
15
16
17
18
19
Mon
20
21
22
23
0
1
Rx1
Tx
FrN+1
2
3
Rx2
Tx
W1(Rx)
4
5
6
7
8
9
10
Tx1
Rx
11
12
Tx2
Rx
W2(Tx)
13
14
15
16
17
18
19
Mon
20
21
22
23

Fig.5.

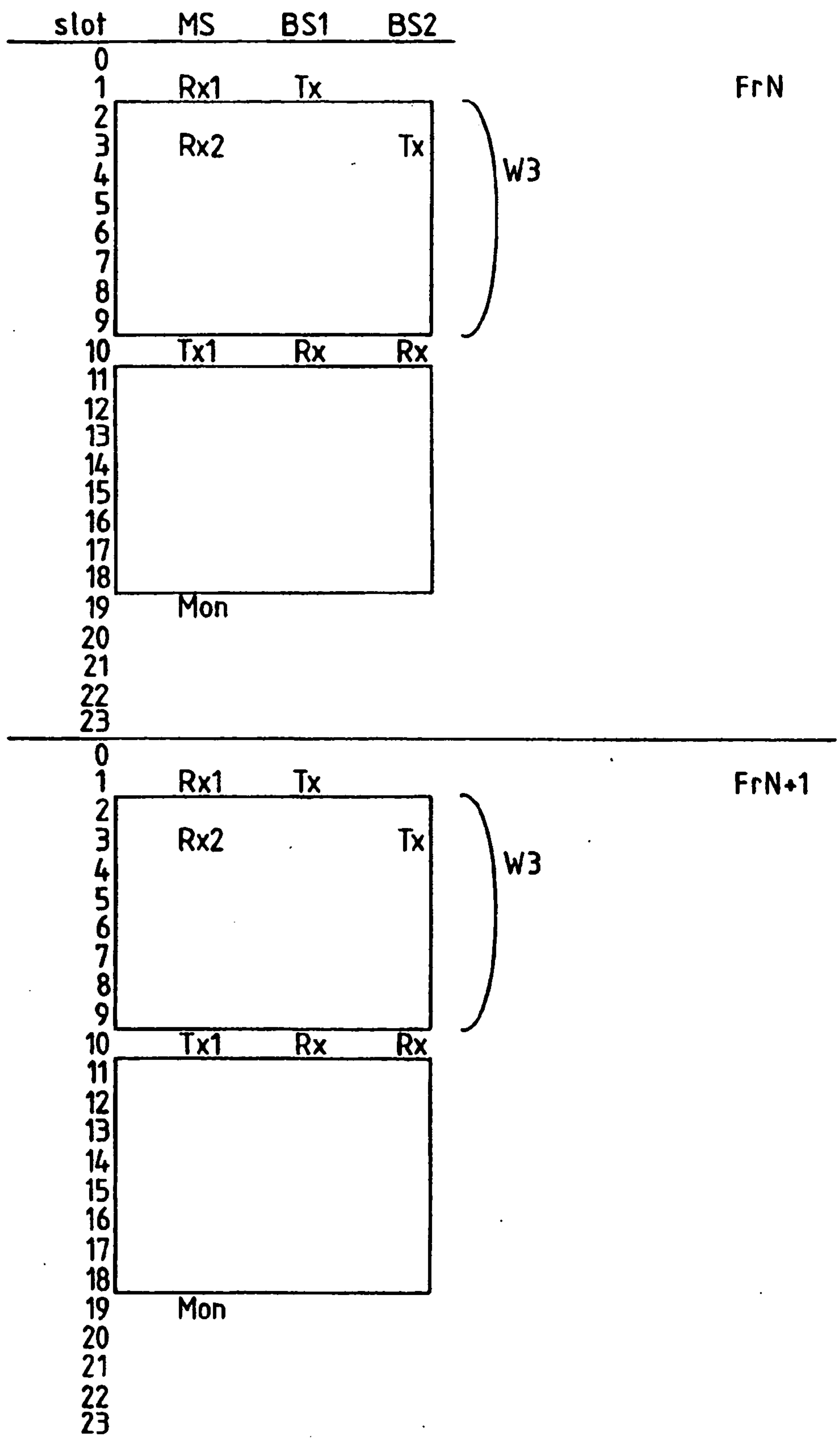
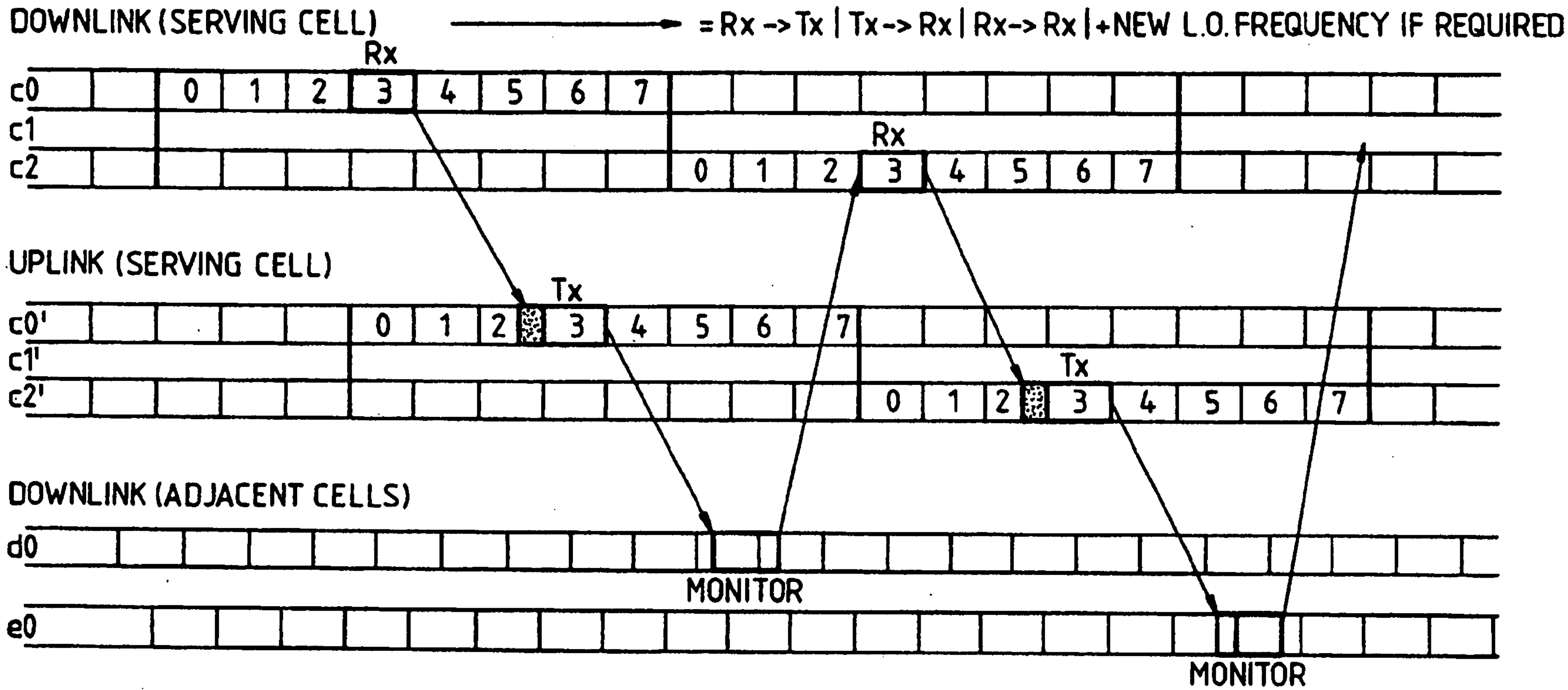

slot
MS
BS1
BS2
0
1
Rx1
Tx
FrN
2
3
Rx2
Tx
W3
4
5
6
7
8
9
10
Tx1
Rx
Rx
11
12
13
14
15
16
17
18
19
Mon
20
21
22
23
0
1
Rx1
Tx
FrN+1
2
3
Rx2
Tx
W3
4
5
6
7
8
9
10
Tx1
Rx
Rx
11
12
13
14
15
16
17
18
19
Mon
20
21
22
23

Fig.6.


DOWNLINK (SERVING CELL)
= Rx -> Tx | Tx -> Rx | Rx -> Rx | + NEW L.O. FREQUENCY IF REQUIRED
Rx
c0
c1
c2
0 1 2 3 4 5 6 7
UPLINK (SERVING CELL)
Tx
c0'
c1'
c2'
DOWNLINK (ADJACENT CELLS)
d0
e0
MONITOR
MONITOR